"Form Syntax" as a contribution to geodesign

A method to measure urban form quantitatively and assist urban design

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“FORM SYNTAX”

AS A CONTRIBUTION TO GEODESIGN:

A METHOD TO MEASURE URBAN FORM QUANTITATIVELY AND ASSIST URBAN DESIGN

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SECTION

01. INTRODUCTION: A NEW DIRECTION OF APPLYING GEODESIGN APPROACH INTO URBAN DESIGN

01.1 GEODESIGN & URBAN DESIGN

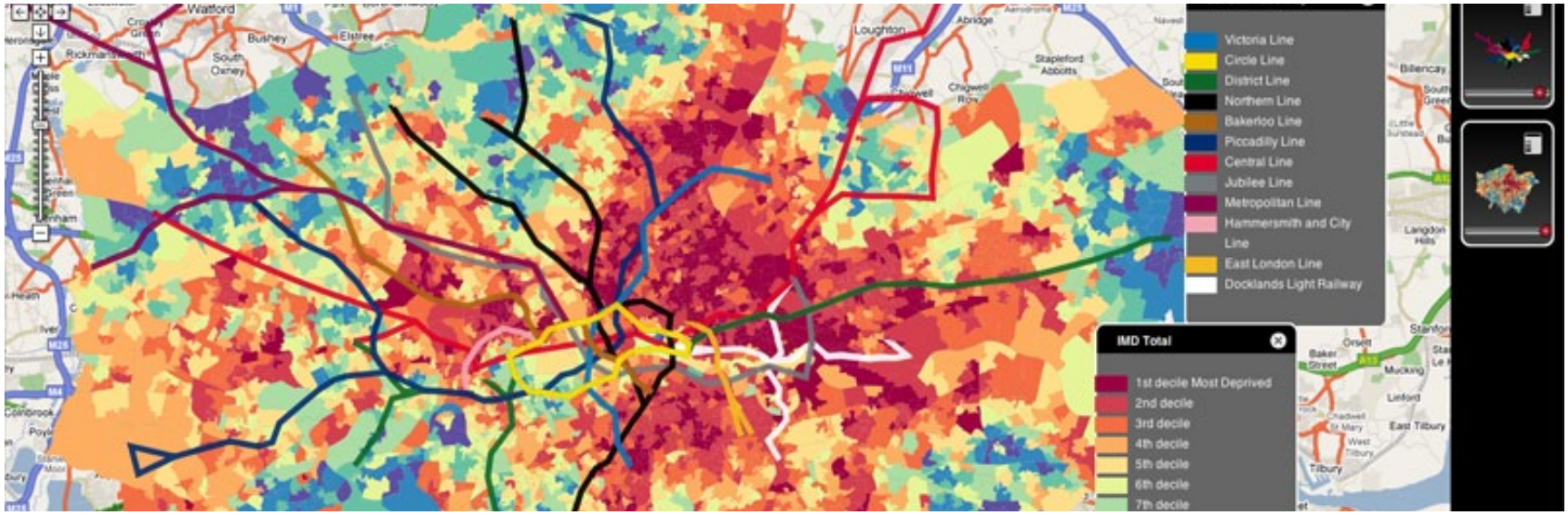
Geodesign is a design method based on geographic contexts to create design proposals (Flaxman, 2010).

Urban design is a design effort to analyse, organise and shape urban form to create lively urban space (Buchanan, 1988; Mumford, 2009).

Apparently, the geodesign could be an important help for urban design practices.

01.1 GEODESIGN & URBAN DESIGN

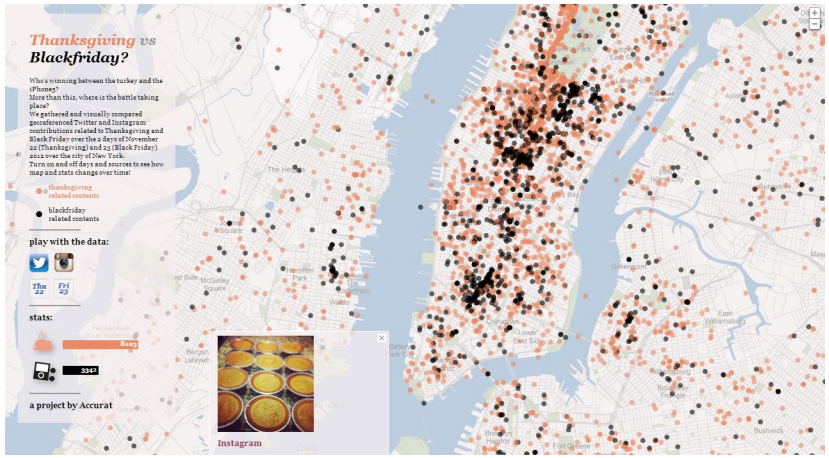
However, the applying of geodesign is limited in the urban design field although many tools have provided a lot of help for landscape and urban planning.



1) **NOT based on urban form - the key issue of urban design**
2) **NOT follow traditional urban design thinking**

O1.2 URBAN DESIGN CALLS FOR NEW ANALYITCAL TOOLS

Meanwhile, **urban design is changing** toward more analytical considerations to handle multiple challenges.

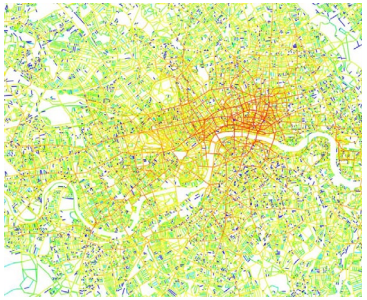


Analysis and evaluation tools **are calling by practitioners, especially the tools able to focus on urban form and can be understood by designers.**

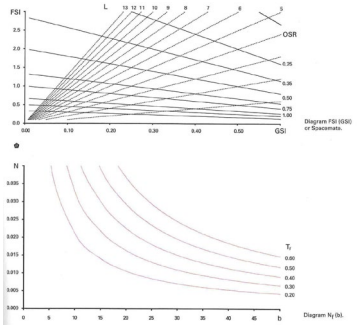
O1.3 TOOLS DEVELOPED BY DESIGNERS THEMSELVES PROVIDE A NEW DIRECTION

New morphological analysis tools have provided quantitative ways to describe many aspects of urban form. **As proposed by designers and morphologists, they can easily be accepted and used into design process.**

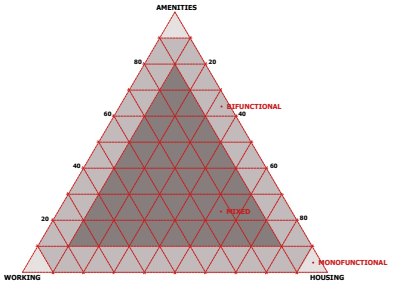
SPACE SYNTAX
Measuring street network configuration.



SPACEMATRIX
Measuring building density and building types



MXIED USE INDEX (MXI)
Measuring the degree of functional mixture



These improvements raise a new direction of extending geodesign approach into urban design.
In this context, **Form Syntax** is proposed as **a quantitative method to analyse urban form based on urban morphology tradition and able to follow urban design thinking.**

SECTION

02.

FORM SYNTAX AS
A QUANTITATIVE DESCRIPTION OF URBAN FORM

02.1 THE THEORETICAL FOUNDATIONS OF FORM SYNTAX

Conzen's "town-plan analysis" includes:

(1) town plans (streets, plots, and buildings),
(2) patterns of building form,
(3) patterns of land use

The essential properties of urban form can be regarded as:

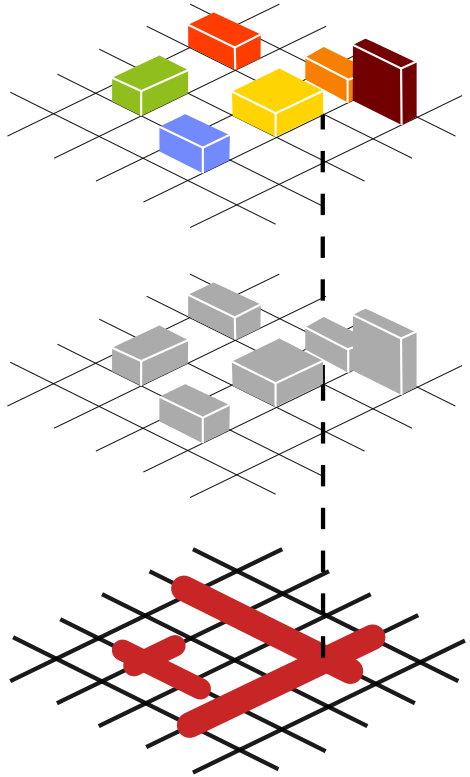
(1) the **street** system,
(2) the **building** system
(plots and the buildings located on it)
(3) the **land use** pattern.

UNDERSTANDING URBAN FORM
FROM ITS ESSENTIAL PROPERTIES

LAND USE
MIXED USE INDEX (MXI)

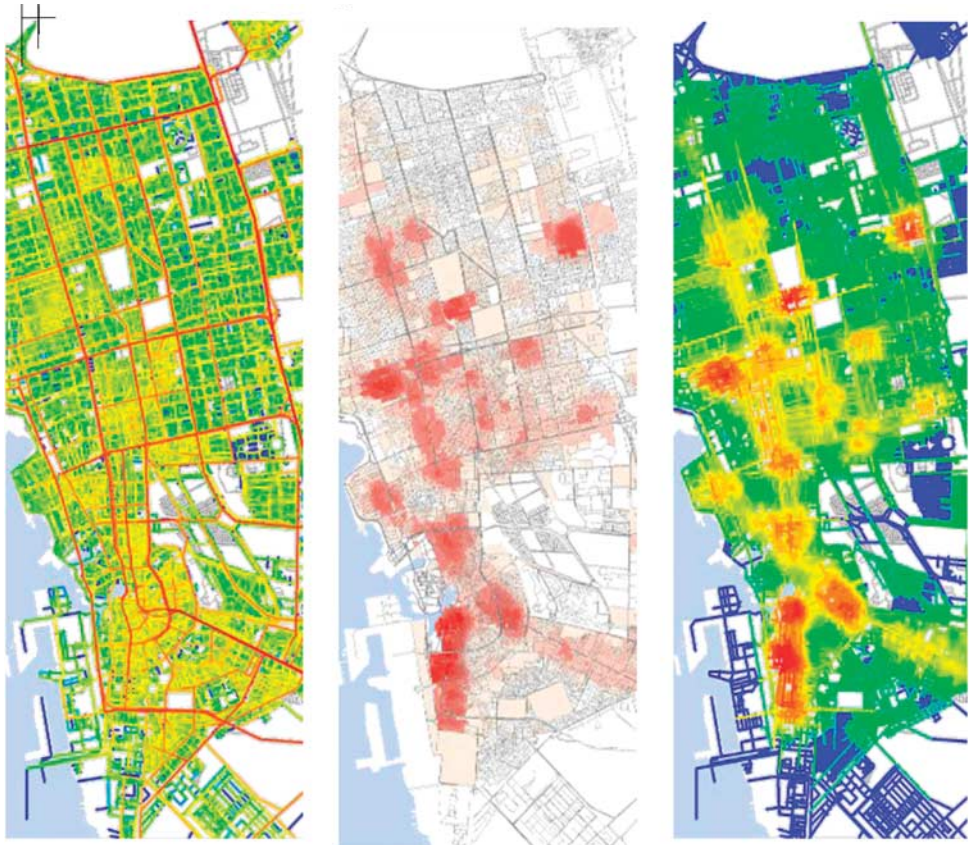
DENSITY & BUILDING TYPES
SPACEMATRIX

STREET NETWORK
SPACE SYNTAX

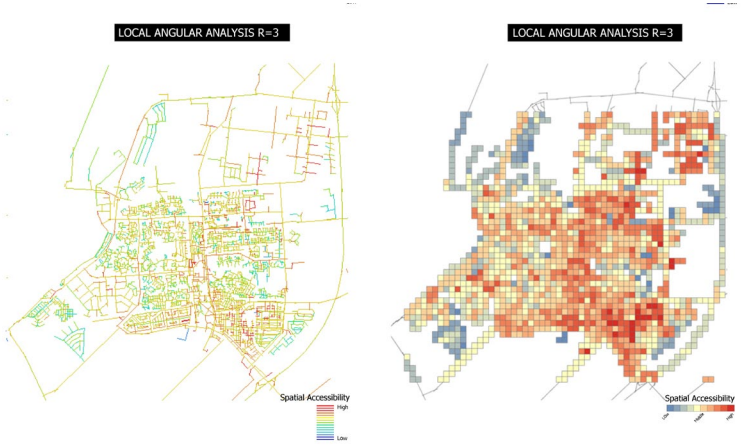


02.2 THREE RELATED SPATIAL ANALYSIS TOOLS: SPACE SYNTAX, SPACEMATRIX & MXI

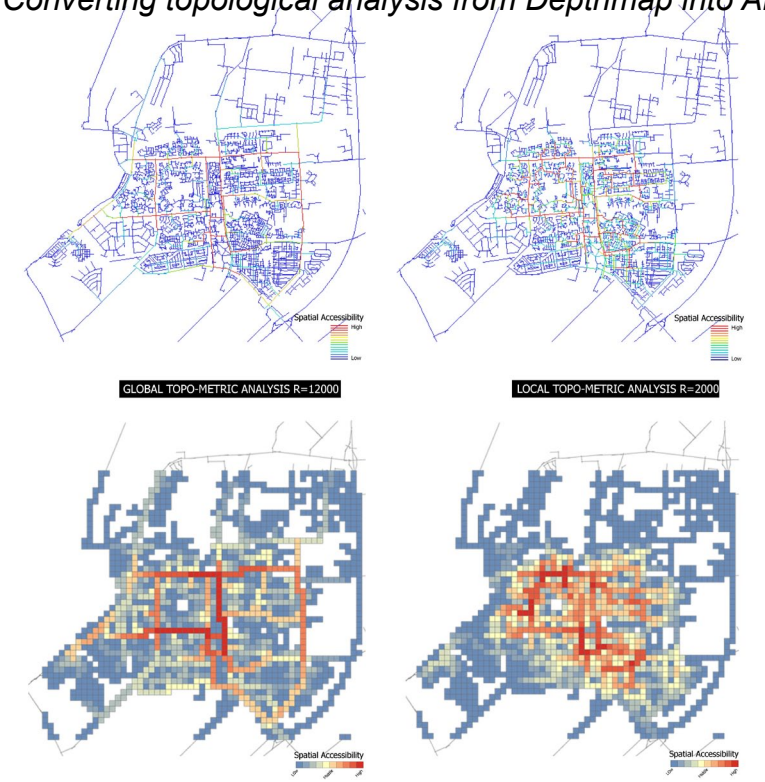
The space syntax includes a set of techniques for analysing the street network configuration. Although applying only space syntax to describe the whole built environment contains some problems, the potential of integrating street network analysis with other layers of data to reveal the urban form has been well recoginzed.



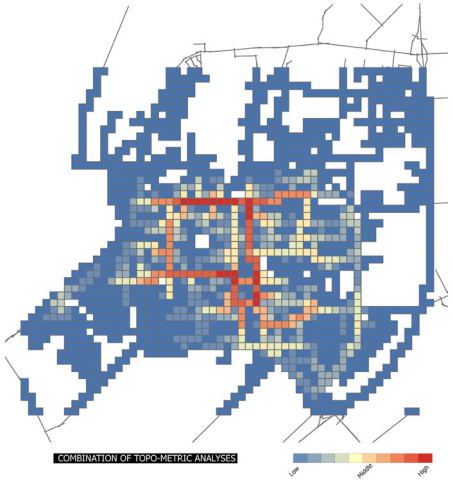
02.2 THREE RELATED SPATIAL ANALYSIS TOOLS: SPACE SYNTAX, SPACEMATRIX & MXI



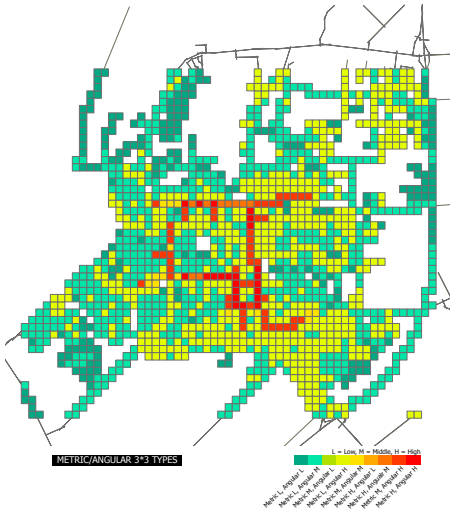
Converting topological analysis from Depthmap into ArcGIS



Converting metric analysis from Depthmap into ArcGIS



The combination of metric analyses



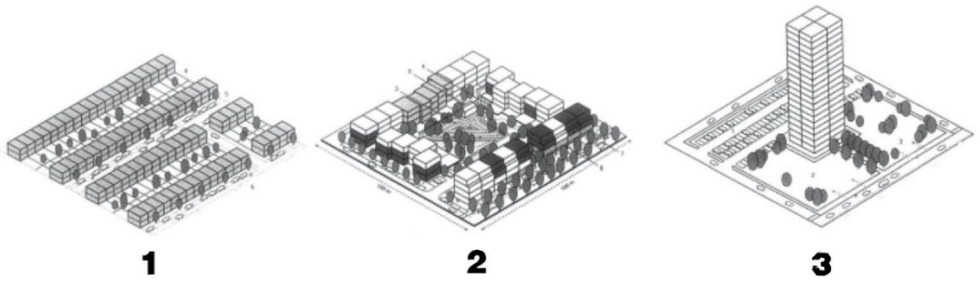
Example of spatial integration analyses

Space Syntax analyses	Angular analyses with topological radii	Angular analyses with metric radii
High level	High level	High level
	Middle level	High level
	High level	Middle level
Middle level	Middle level	Middle level
	High level	Low level
	Low level	High level
Low level	Middle level	Low level
	Low level	Middle level
	Low level	Low level

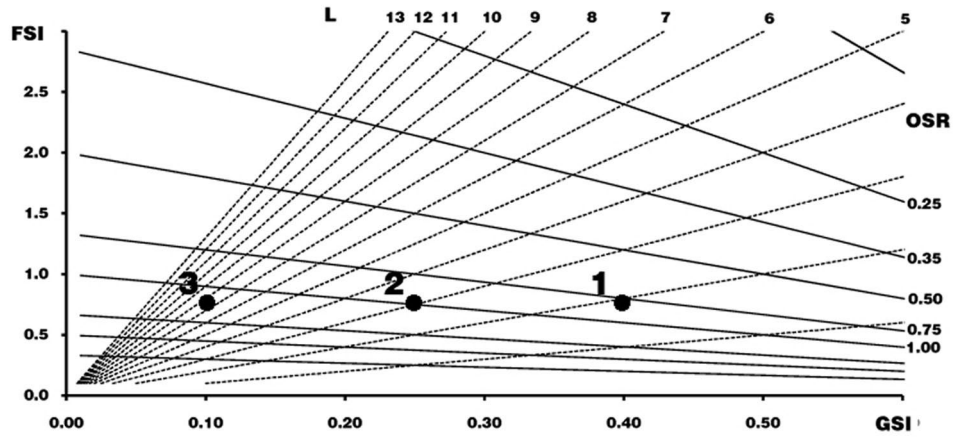
PRINCIPLES OF COMBINATION: SPACE SYNTAX ANALYSES

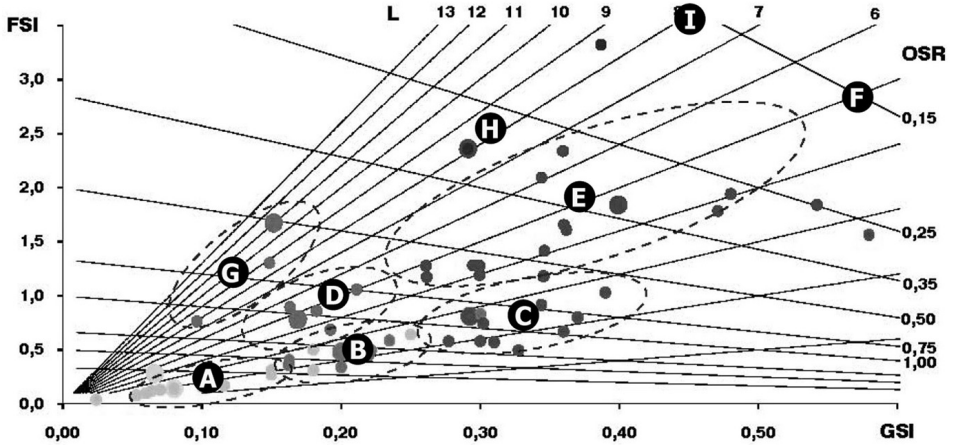
02.2 THREE RELATED SPATIAL ANALYSIS TOOLS: SPACE SYNTAX, SPACEMATRIX & MXI

The spacematrix method contributes to co-present building density and building types at the same time.

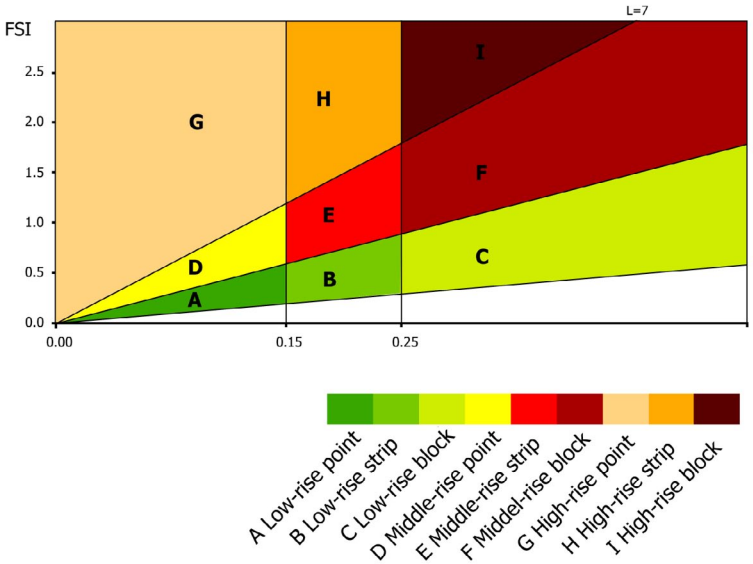


G: high-rise point type
H: high-rise strip type
I: high-rise block type
D: mid-rise point type
E: mid-rise strip type
F: mid-rise block type
A: low-rise point type
B: low-rise strip type
C: low-rise block type





02.2 THREE RELATED SPATIAL ANALYSIS TOOLS: SPACE SYNTAX, SPACEMATRIX & MXI



High level: E; F; I

Middle level: C; D; G; H

Low level: A; B

G: high rise point type

H: high rise strip type

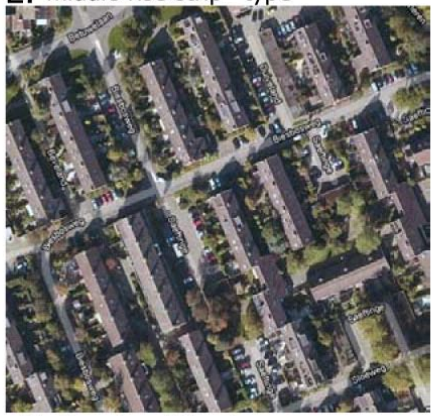
I: high rise block type

D: middle rise point

E: middle rise strip type

F: middle rise block type

A: low rise point type

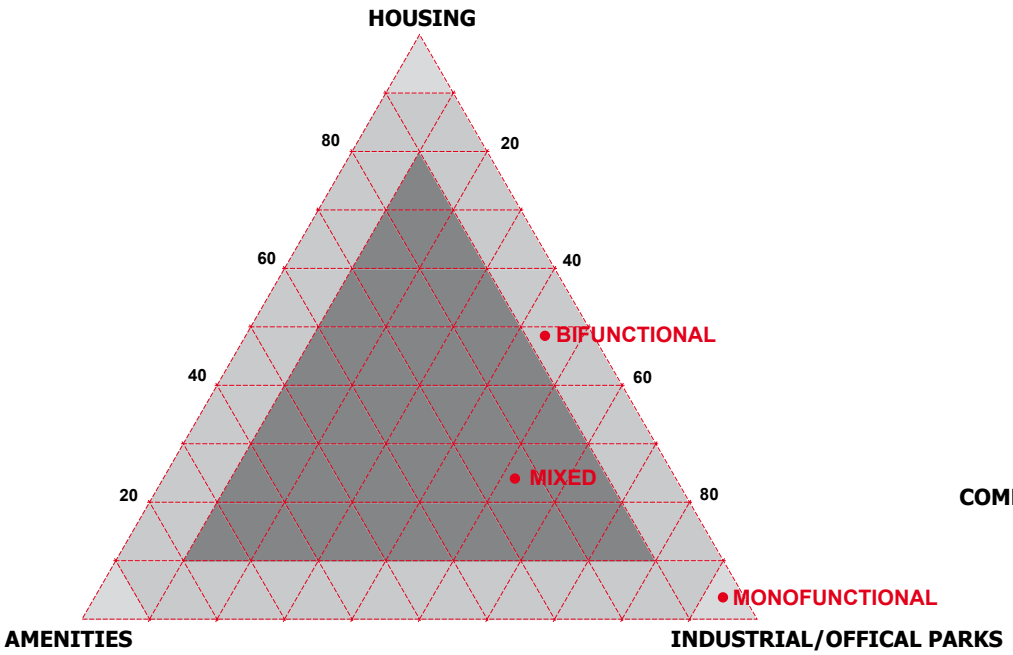


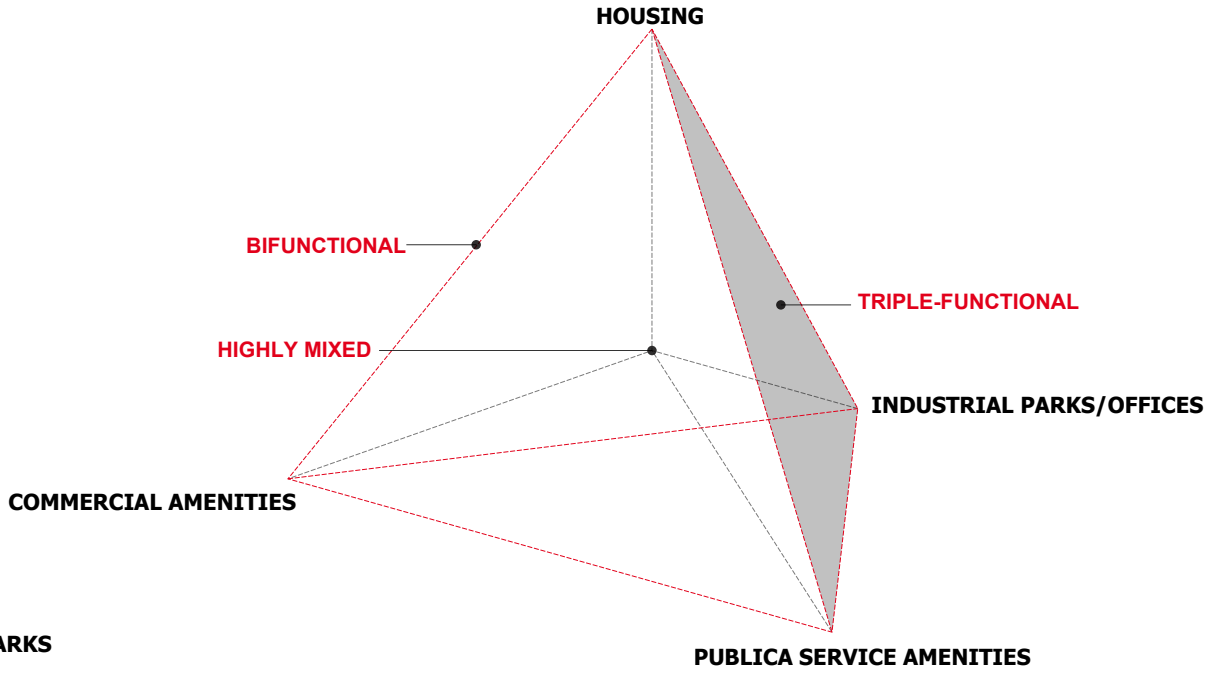
B: low rise strip type

C: low rise block type

02.2 THREE RELATED SPATIAL ANALYSIS TOOLS: SPACE SYNTAX, SPACEMATRIX & MXI

The mixed use index (MXI) is developed by van den Hoek (2008, 2009) to measure various degrees of multi-functionality of land use: "housing"; "working" and "amenities"





02.2 THREE RELATED SPATIAL ANALYSIS TOOLS: SPACE SYNTAX, SPACEMATRIX & MXI

LOW-LEVLE

Working

Housing

Public Amenities

Commercial Amenities

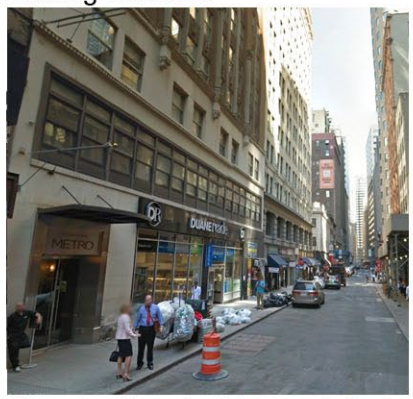
MID-LEVLE

Two functional mixture: in the example of commercial+housing

Three functional mixture without housing functions

HIGH-LEVLE

Three functional mixture containing housing funcions: relatively low



Four functional mixture: relatively high

02.3 FORM SYNTAX: COMBINING THE THREE TOOLS TO QUANTIFY URBAN FORM

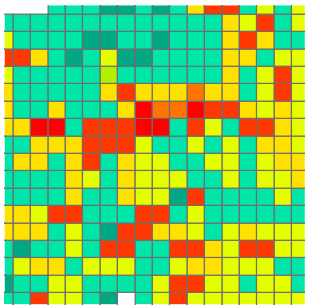
ESSENTIAL PROPERTIES OF URBAN FORM BASED ON GRIDS

SPACE SYNTAX

STREET NETWORK CONFIGURATION

LINEAR BASED

TRANSFER



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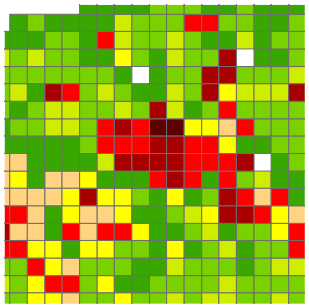
SPACEMATRIX

BUILDING DENSITY & TYPES

AREA BASED

TRANSFER



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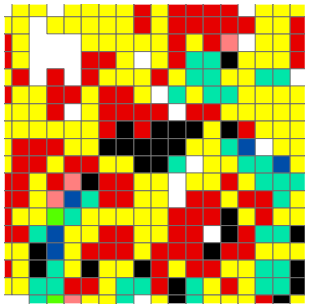
MIXED USE INDEX (MXI)

LAND USE MIX

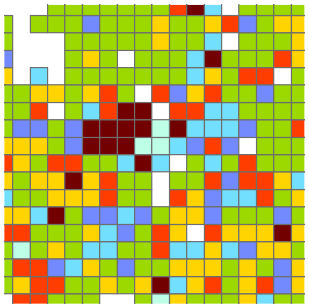
AREA BASED

TRANSFER



OVERLAPPING

COMBINED SPATIAL PROPERTIES REPRESENTING URBAN FORM



With the help of GIS, different spatial properties can be transfered into grid-based data, and then combined together to **quantify urban form.**

02.4 BUILDING A SPATIAL CLASSIFICATION OF URBAN FORM VIA FORM SYNTAX

Defining **high, medium and low values** in the three measurements and then combining them together to **classify urban form.**

Table 1. The definition of high, medium and low values in space syntax, spacematrix and MXI

Space Syntax	The content of this classification
High value	High values in both metric and topological analyses; One analysis with high value and the other with medium value
Medium value	Medium values in both metric and topological analyses; One analysis with high value and the other with low value
Low value	Low values in both metric and topological analyses One analysis with medium value and the other with low value

Spacematrix	The content of this classification
High value	Mid-rise strip or block types; high-rise block types
Medium value	Low-rise block or mid-rise point; high-rise point or strip types
Low value	Low-rise point and low-rise strip types

MXI	The content of this classification
High value	Mixture of four functions; all three functional mix containing housing
Medium value	Bifunctional areas; three functional mix does not contain housing
Low value	Monofunctional areas

02.4 BUILDING A SPATIAL CLASSIFICATION OF URBAN FORM VIA FORM SYNTAX

Classifying urban form into seven categories and three groups

Table 2. Seven categories of urban form defined by the three essential properties

Categories of urban form	The values of Space Syntax, Spacematrix and MXI	Degree of Balance
Category I	L/L/L, M/L/L, L/L/M, L/M/L	Balanced with low-values
Category II	L/M/M, M/L/M, M/M/L	
Category III	H/L/L, L/H/L, L/L/H	Unbalanced with mixed-values
Category IV	H/M/L, M/H/L, L/M/H, H/L/M, L/H/M, M/L/H	
Category V	H/H/L, H/L/H, L/H/H	
Category VI	M/M/H, M/H/M, H/M/M, M/M/M	Balanced with high-values
Category VII	H/H/H, H/M/H, M/H/H, H/H/M	

L = Low value, M = Medium value, H = High value

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SECTION

03.

FORM SYNTAX AS
A MORPHOLOGICAL REFLECTION OF URBANITY

03.1 WHAT IS URBANITY?

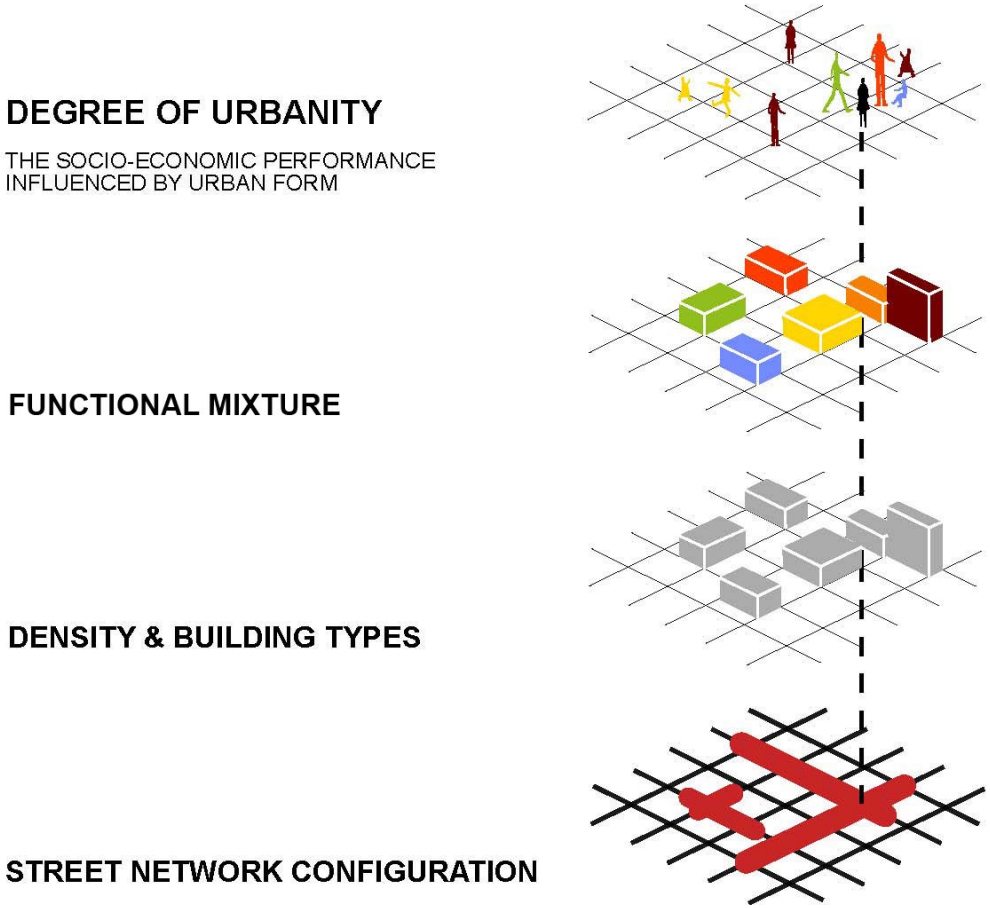
The Concept of Urbanity

For urban sociologists: socio-economic activities & the culture of cities

For architects and urban designers: a spatial quality provided by design

An emerging combined viewpoint: socio-economic performance influenced by urban form

It is possible to measure urbanity from morphological perspective



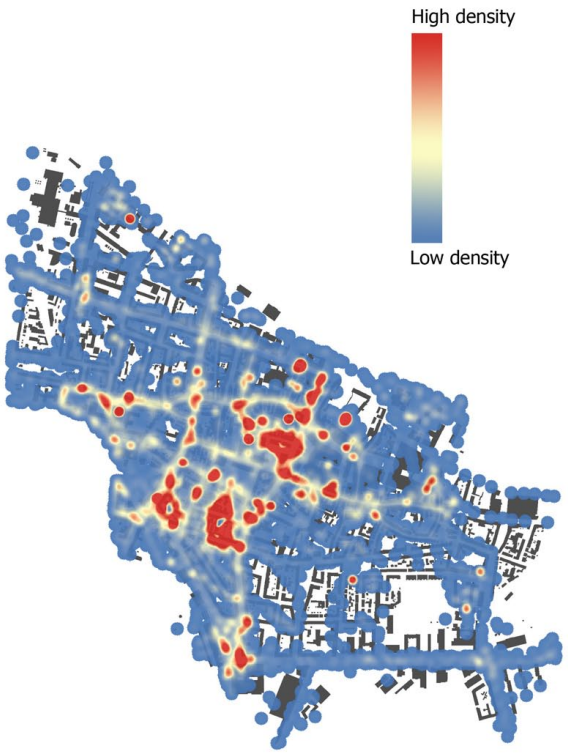
03.2 GPS TRACKING ON HUMAN BEHAVIOURS AS A REFLECTION OF URBANITY FROM A SOCIAL PERSPECTIVE

GPS tracking of pedestrain movements

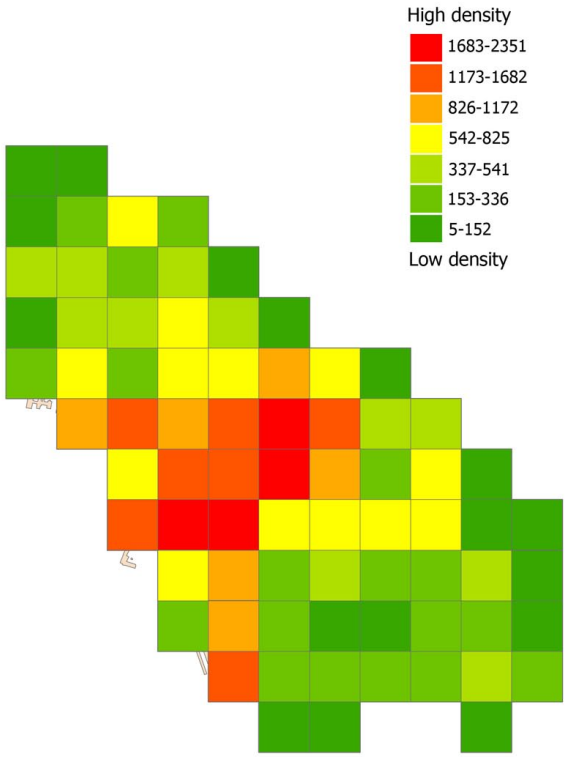
GPS tracking of taxi pick-up and drop-off points

If urban life is, according to Wirth (1938) and Lefebvre (1968), as the gathering of large population size, high population density and heterogeneity, then **human behaviour record can be used to represent as one socio-economic aspect of urbanity.**

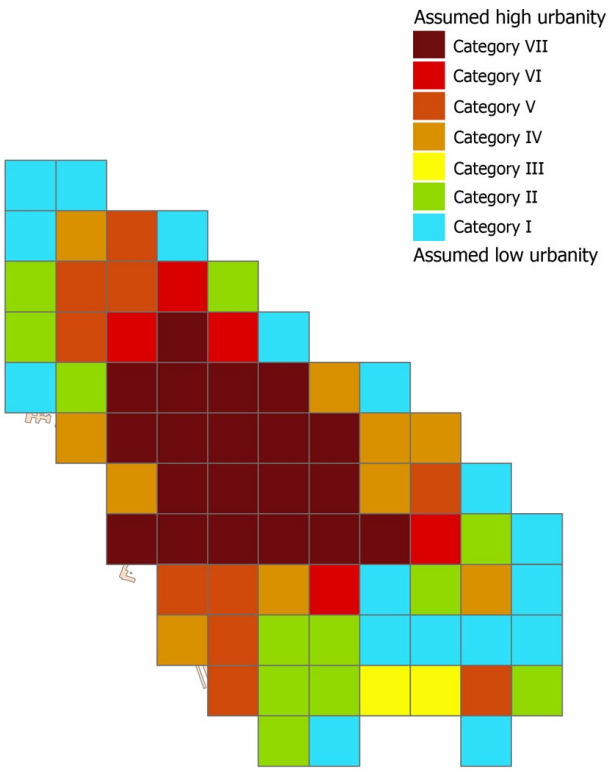
03.3 PEDESTRIAN ACTIVITIES V.S. FORM SYNTAX ANALYSIS IN AALBORG



A. The density of pedestrian behaviours in the historical centre of Aalborg shown as heatmap



B. The rasterised density of pedestrian behaviours in the historical centre of Aalborg



C. Various categories shown morphological characteristics given by Form Syntax analysis

ANOVA between the groups of "assumed degree of urbanity" and "numbers of pedestrian trajectory points in each grid"

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1.298E7	6	2163497.145	9.993	.000
Within Groups	1.494E7	69	216497.070		
Total	2.792E7	75			

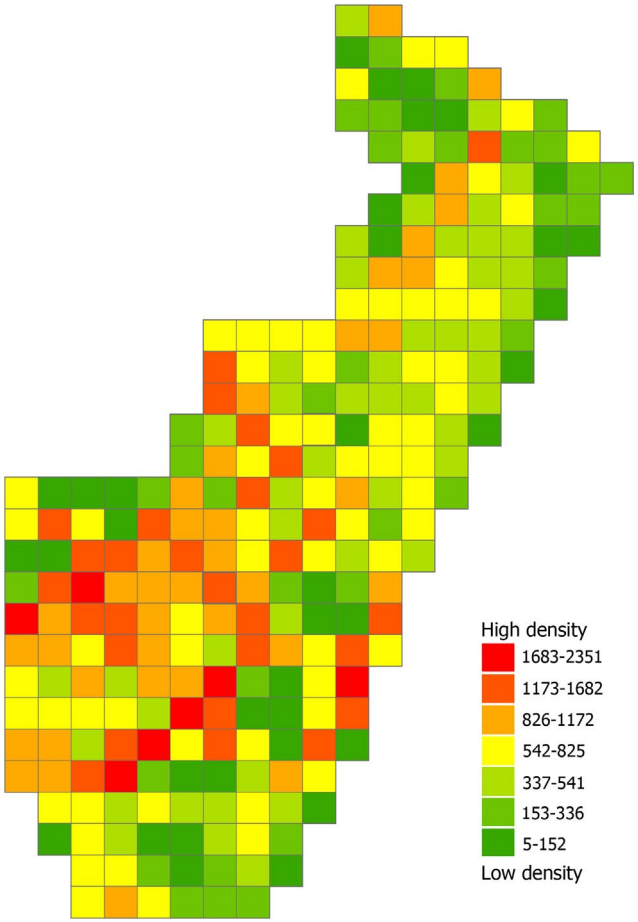
Correlations between "assumed degree of urbanity" and "levels of pedestrian trajectory points"

		Assumed degree of urbanity	Levels of pedestrian trajectory points
Assumed degree of urbanity	Pearson Correlation	1	.823**
	Sig. (2-tailed)		.000
	N	76	76
Levels of pedestrian trajectory points	Pearson Correlation	.823**	1
	Sig. (2-tailed)	.000	
	N	76	76

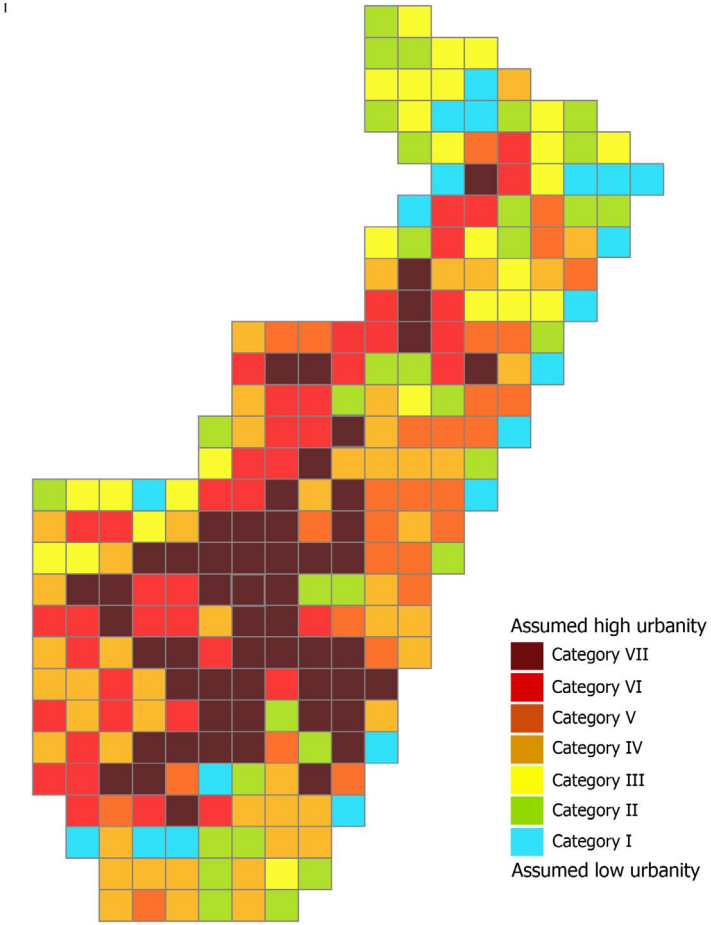
**. Correlation is significant at the 0.01 level (2-tailed).

03.4 TAXI PICK-UP AND DROP-OFF POINTS V.S. FORM SYNTAX ANALYSIS IN WUHAN

A. The density of taxi pick-up and drop-off points in Jiang'an District, Wuhan shown as heatmap



B. The rasterised density of taxi pick-up and drop-off points in Jiang'an District, Wuhan



C. Various categories shown morphological characteristics given by Form Syntax analysis

ANOVA between the groups of "assumed degree of urbanity" and "numbers of of taxi pick up and drop off points in each grid"

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.720E7	6	4532784.518	36.099	.000
Within Groups	3.152E7	251	125565.193		
Total	5.871E7	257			

Correlations between "assumed degree of urbanity" and "levels of density of taxi pick up and drop off points (including car-free areas)

		Assumed degree of urbanity	Levels of density of taxi pick up and drop off points
Assumed degree of urbanity	Pearson Correlation	1	.691**
	Sig. (2-tailed)		.000
	N	258	258
Levels of density of taxi pick up and drop off points	Pearson Correlation	.691**	1
	Sig. (2-tailed)	.000	
	N	258	258

**. Correlation is significant at the 0.01 level (2-tailed).

Correlations between "assumed degree of urbanity" and "levels of density of taxi pick up and drop off points (excluding car-free areas)

		Assumed degree of urbanity	Levels of density of taxi pick up and drop off points
Assumed degree of urbanity	Pearson Correlation	1	.716**
	Sig. (2-tailed)		.000
	N	252	252
Levels of density of taxi pick up and drop off points	Pearson Correlation	.716**	1
	Sig. (2-tailed)	.000	
	N	252	252

**. Correlation is significant at the 0.01 level (2-tailed).

03.5 FORM SYNTAX AS A MEASUREMENT OF URBANITY FROM MORPHOLOGICAL PERSPECTIVE

Table 3. Form Syntax as a morphological reflection of urbanity

Urbanity	The division of values from space syntax, spacematrix and MXI	Examples
1) Suburban	L/L/L, M/L/L, L/L/M, L/M/L	
2) Low urban	L/M/M, M/L/M, M/M/L	
3) In-between (low) 4) In-between (medium) 5) In-between (high)	H/L/L, L/H/L, L/L/H H/M/L, M/H/L, L/M/H, H/L/M, L/H/M, M/L/H H/H/L, H/L/H, L/H/H	
6) Medium urban	M/M/H, M/H/M, H/M/M, M/M/M	
7) highly urban	H/H/H, H/M/H, M/H/H, H/H/M	

L = Low values, M = Medium values, H = High values

Table 2. Seven c

Categories of urban form	Degree of Balance
Category I Category II	Balanced with low-values
Category III Category IV Category V	Unbalanced with mixed-values
Category VI Category VII	Balanced with high-values

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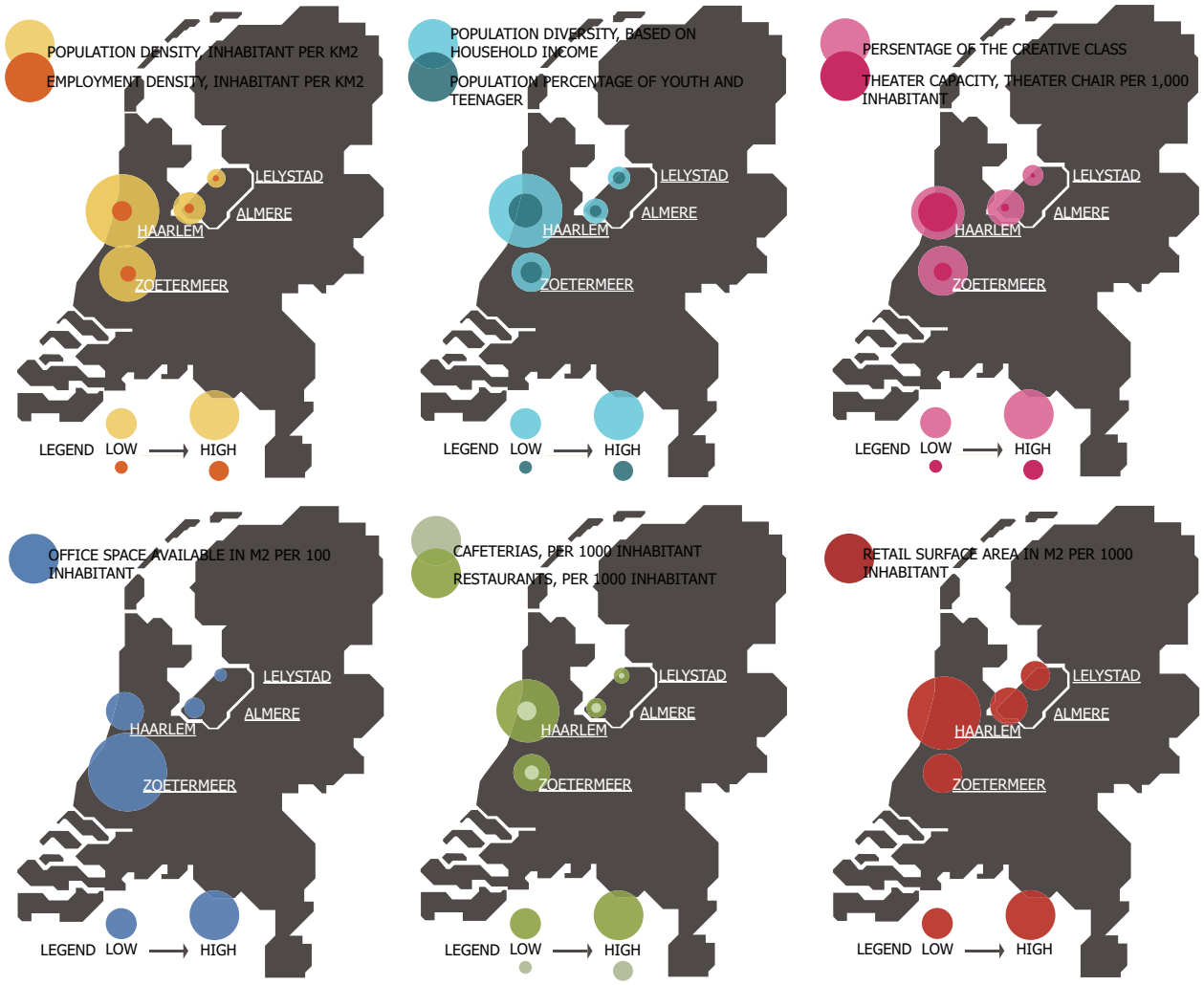
SECTION

04.

MAKING A SPATIAL EXPLORATION OF UNBALANCED AREAS WITH FORM SYNTAX

O4.1 THE UNBALANCED AREA IS THE KEY

A set of towns in Netherlands are chosen to study the changing percentages of various “balance" & "unbalance" groups.



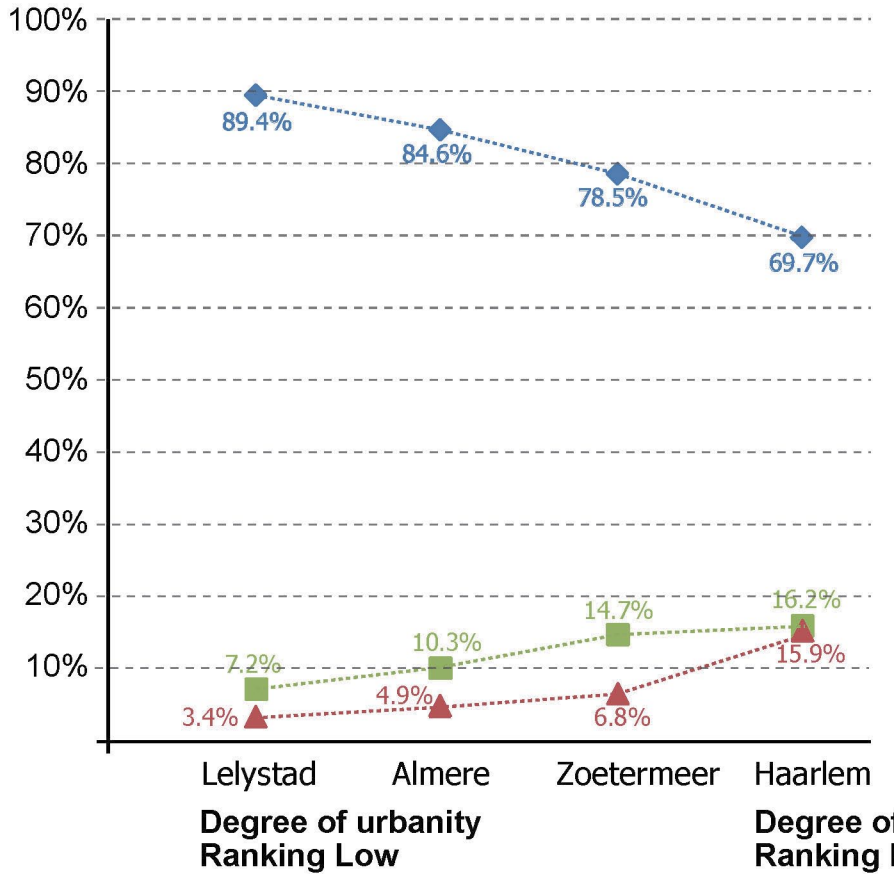
'Haarlem > Zoetermeer > Almere > Lelystad' The ranking of urbanity

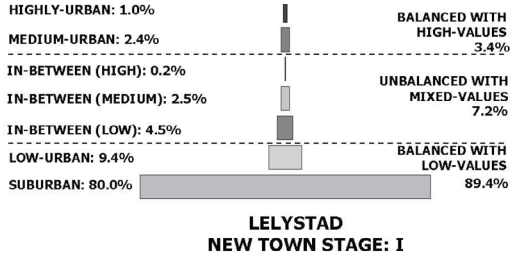
Historical city Well developed new town Poor developed new town

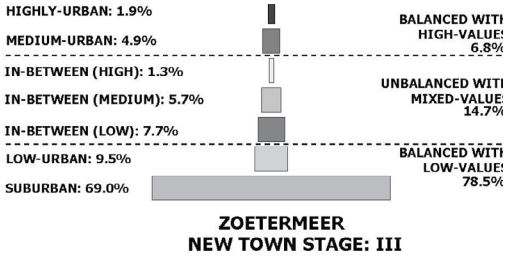
O4.1 THE UNBALANCED AREA IS THE KEY

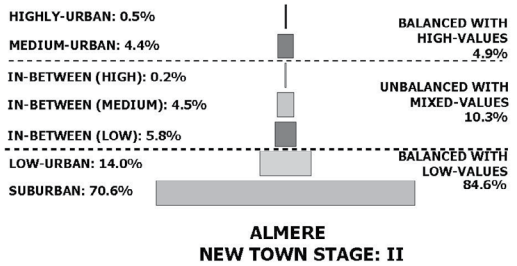
With the increase of urbanity, there are two routes exist at the same time: 1) from "balanced with low value" to both "unbalanced" and "banlaced with high value" 2) from "unbalanced" to "banlaced with high value".

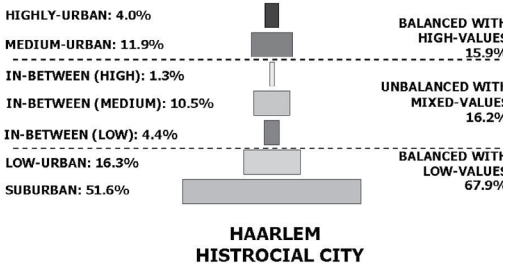
The second route: transforming unbalanced areas toward balanced with high values are more important:
1) it is much easier to promote unbalanced areas towards balanced with high value areas
2) "balanced with low values" is not a negative description

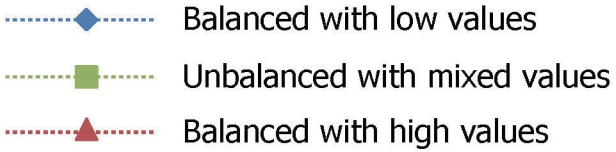








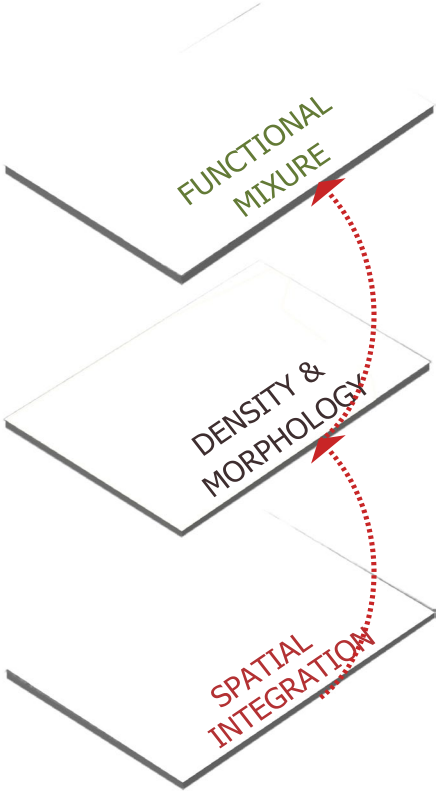




O4.2 UNDERSTANDING INTERRELATIONSHIP BETWEEN STREET NETWORK, DENSITY AND MIX

What kind of interventions should be proposed for developing the unbalanced groups? To answer this question needs a further study on the interrelationship between the three morphological properties.

Street networks: thousands of years
Buildings: about 100 years
Functions: changing constantly



Spatial integration tends to be the foundation supporting the other two properties. Likewise, density & building types influence functional mix as well.

City	Values	Spatial integration	Mix	Density
Lelystad	High	80 (7.2%)	7 (0.6%)	36 (3.2%)
	Middle	475 (42.8%)	172 (15.5%)	90 (8.1%)
	Low	556 (50.0%)	932 (83.9%)	985 (88.7%)
Almere	High	160 (7.9%)	22 (1.1%)	96 (4.8%)
	Middle	1007 (49.8%)	322 (15.9%)	292 (14.5%)
	Low	853 （42.3%）	1676 (83.0%)	1632 (80.7%)
Zoetermeer	High	78 (7.6%)	47 (4.5%)	91 (8.8%)
	Middle	405 (39.2%)	312 (30.2%)	240 (23.3%)
	Low	540 (52.2%)	674 (65.3%)	712 (68.9%)
Haarlem	High	103 (6.9%)	166 (11.1%)	231 (15.5%)
	Middle	541 (36.3%)	521 (34.9%)	455 (30.5%)
	Low	848(56.8%)	805 (54.0%)	806 (54.0%)

City	Maturation process	Spatial integration	Mix	Density
Lelystad	STAGE I: Begining			
Almere	STAGE II: Developing			
Zoetermeer	STAGE III: Developed			
Haarlem	Historically-evolved city			

04.3 IDENTIFYING VARIOUS POTENTIALS IN UNBALANCED GROUPS

We can **classify the "unbalanced group"** and **identify various kinds of potentials** based on the interrelationship of three properties

Table 4. The classification of various potentials in unbalanced areas

In-between (low): High, Low, Low			
Potentials	A	B	D=A+B
MXI	Low	Low	High
Spacematrix	Low	High	Low
Space Syntax	High	Low	Low

In-between (medium): High, Medium, Low						
Potentials	E=A+C	A	C	A	B	B
MXI	Low	Medium	Low	High	High	Medium
Spacematrix	Medium	Low	High	Low	Medium	High
Space Syntax	High	High	Medium	Medium	Low	Low

In-between (high): High, High, Low			
Potentials	C	B	A
MXI	Low	High	High
Spacematrix	High	High	Low
Space Syntax	High	Low	High

A: Potential for densification / morphological developments
B: Potential for spatial integration developments
C: Potential for land-use mix developments
D: Containing both potentials as described under point A and B
E: Containing both potentials as described under point A and C

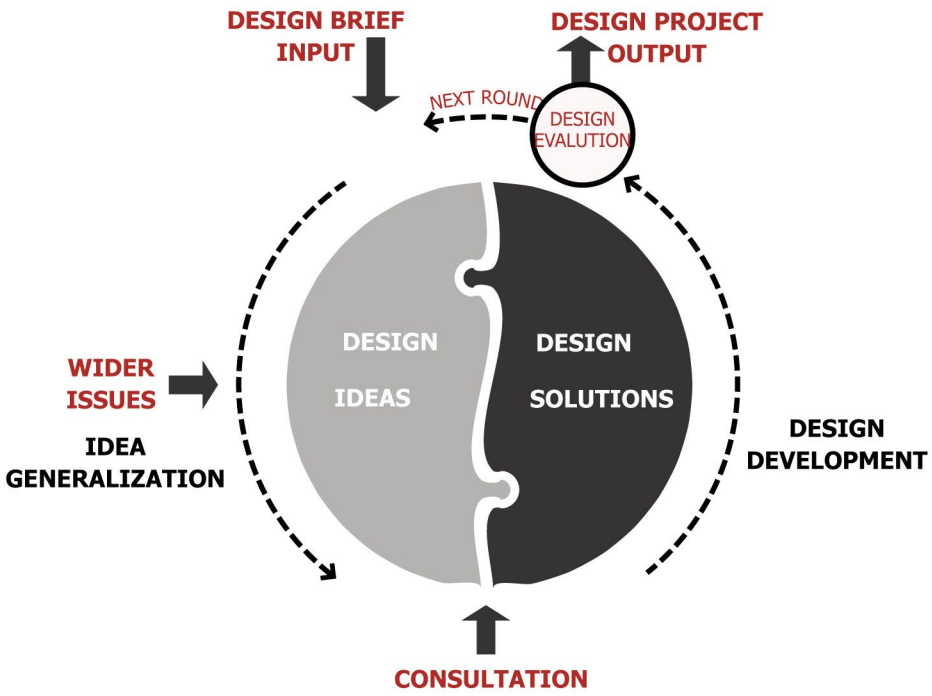
SECTION

05.

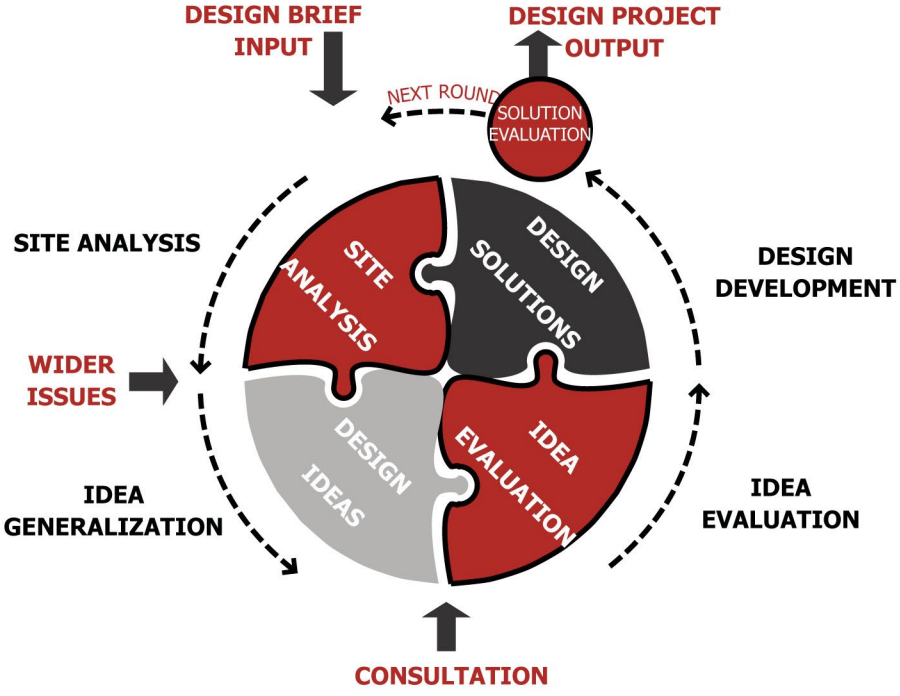
FORM SYNTAX AS
A TOOL TO ASSIST URBAN DESIGN

05.1 HOW FORM SYNTAX ABLE TO ASSIST URBAN DESIGN

The Form Syntax provides a new way to help the three key processes of urban design:
site analysis, idea evaluation and solution evaluation



CURRENT URABN DESIGN PROCESS



ANALYTICAL URABN DESIGN PROCESS APPLYING FORM SYNTAX

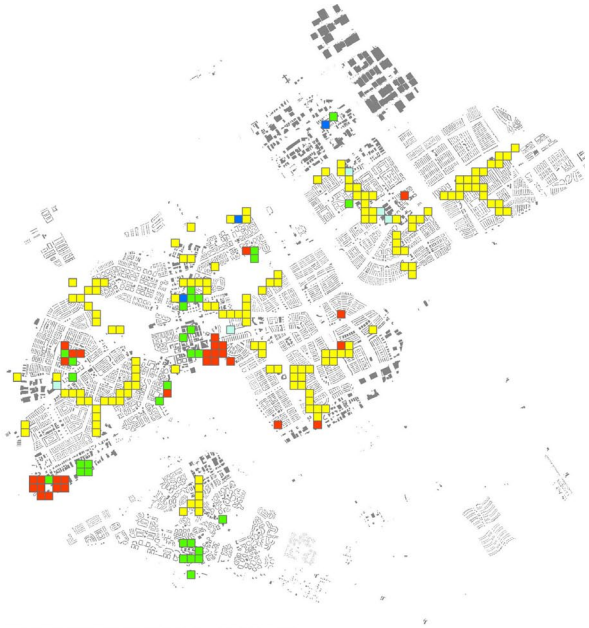
05.2 THE EXAMPLE OF SITE ANALYSIS

Pointing out **where potential areas are and what kinds of interventions should be given** for seeking a higher degree of urbanity.

NEW TOWN STAGE 1: LELYSTAD

CATEGORY OF POTENTIALS

- **A: densification 57**
- **B: spatial integration 10**
- **C: functional mixture 9**
- **D: A+B 0**
- **E: A+C 5**



NEW TOWN STAGE 2: ALMERE

CATEGORY OF POTENTIALS

- **A: densification 145**
- **B: spatial integration 30**
- **C: functional mixture 30**
- **D: A+B 3**
- **E: A+C 5**

NEW TOWN STAGE 3: ZOETERMEER

CATEGORY OF POTENTIALS

- **A: densification 55**
- **B: spatial integration 43**
- **C: functional mixture 16**
- **D: A+B 12**
- **E: A+C 5**

EXAMPLES FOR POTENTIAL AREAS IN NEW TOWNS

A: potential for densification / morpholigical improvements

B: potential for spatial integration improvements

C: groud floor / design level improvements

D: potential for densification/ morphology+ integration improvements

E: potentialpotential for densification/ morphology+ ground floor improve

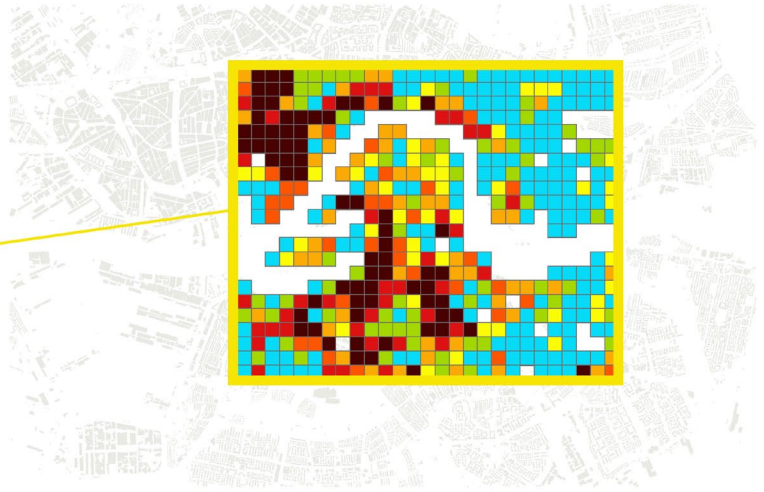
05.3 THE EXAMPLE OF IDEA EVALUATION

Predicting the assumed impacts of design ideas on urbanity

A. Present Rotterdam

B. Analysis of Rotterdam via Form Syntax

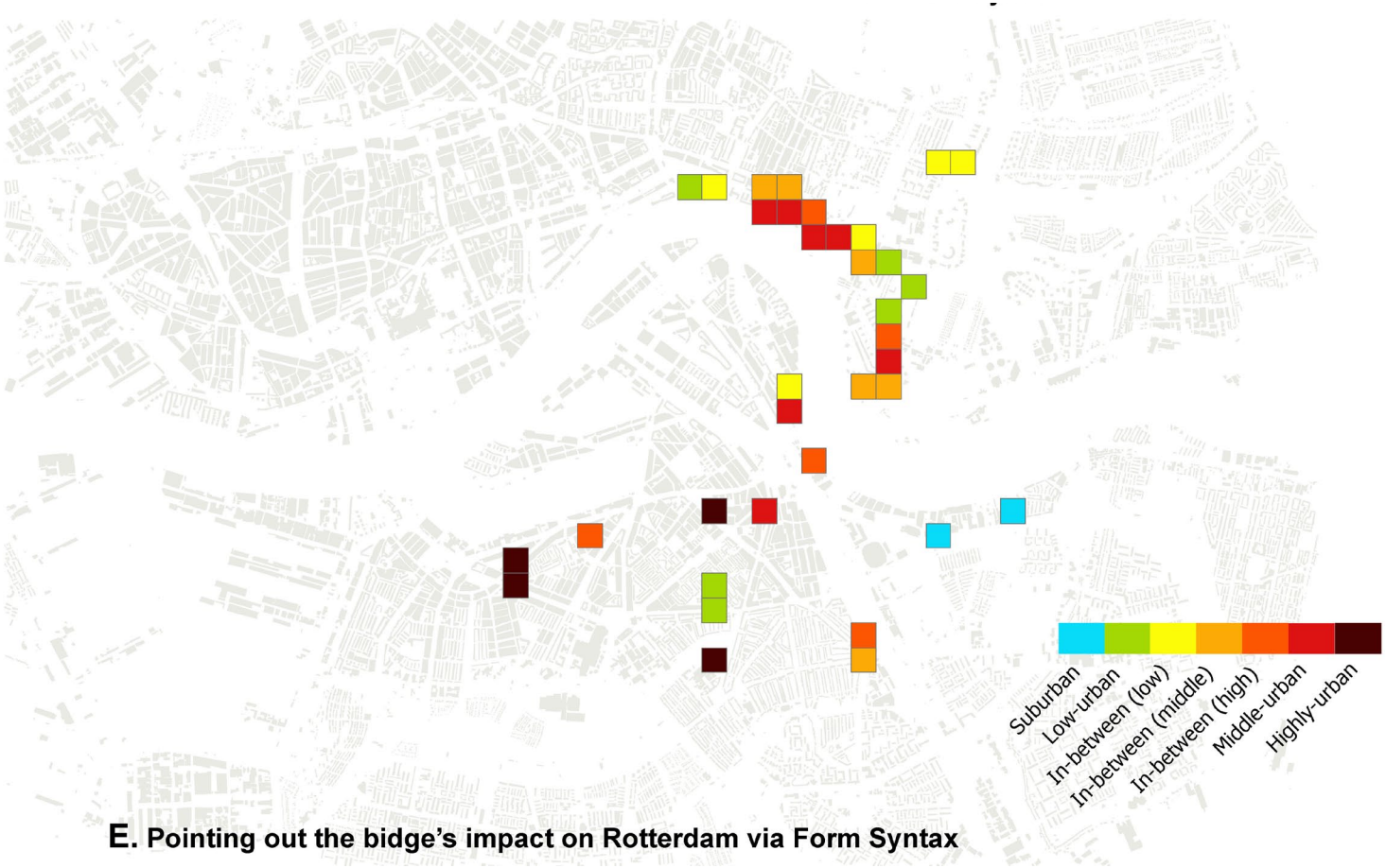
C. Rotterdam with a new bridge



D. Analysis of Rotterdam with a new bridge via Form Syntax

05.3 THE EXAMPLE OF IDEA EVALUATION

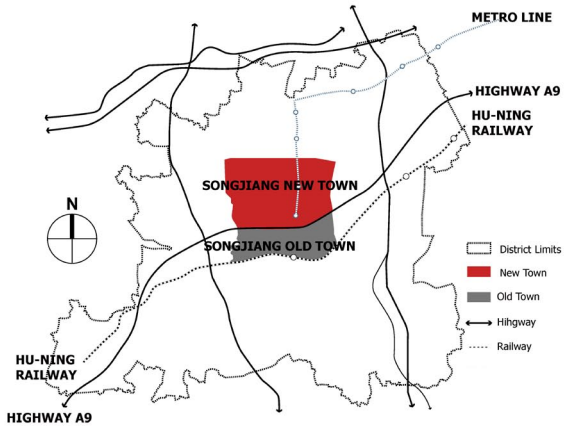
Predicting the assumed impacts of design ideas on urbanity



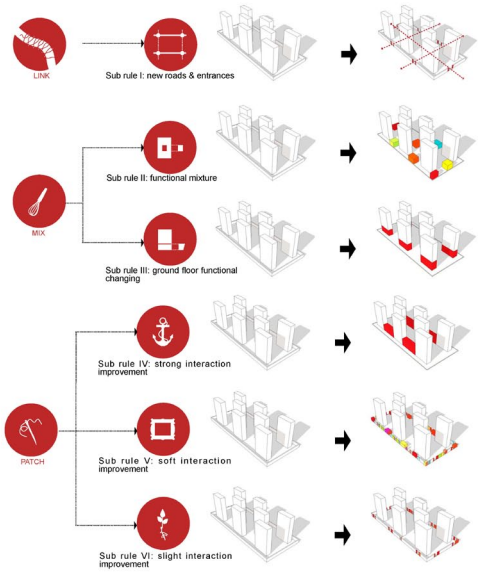
E. Pointing out the bidge's impact on Rotterdam via Form Syntax

05.4 THE EXAMPLE OF SOLUTION EVALUATION

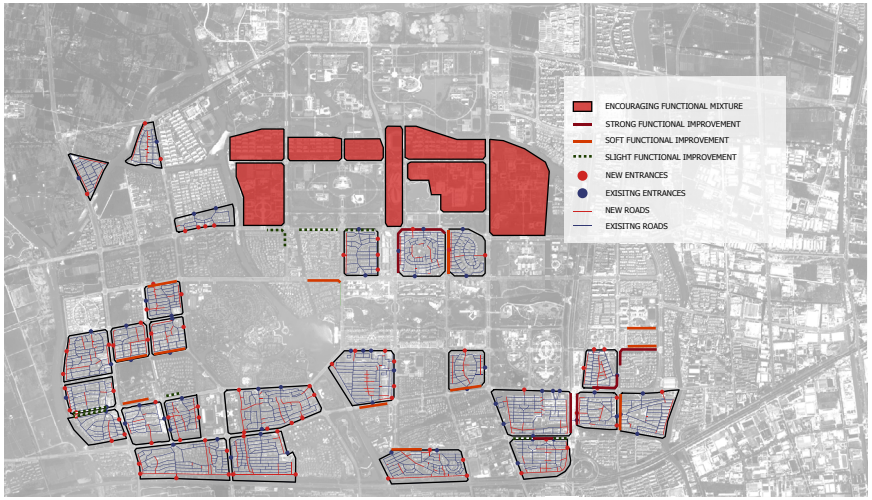
Judging the impacts of design interventions by illustrating a before-and-after situation

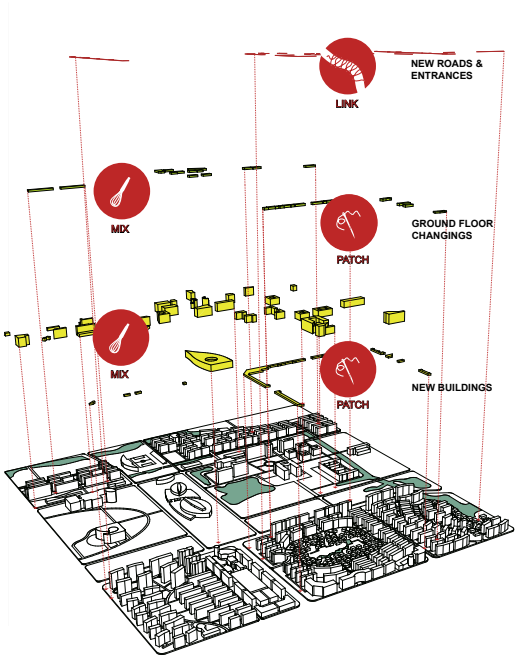


A. The location of Songjiang new town



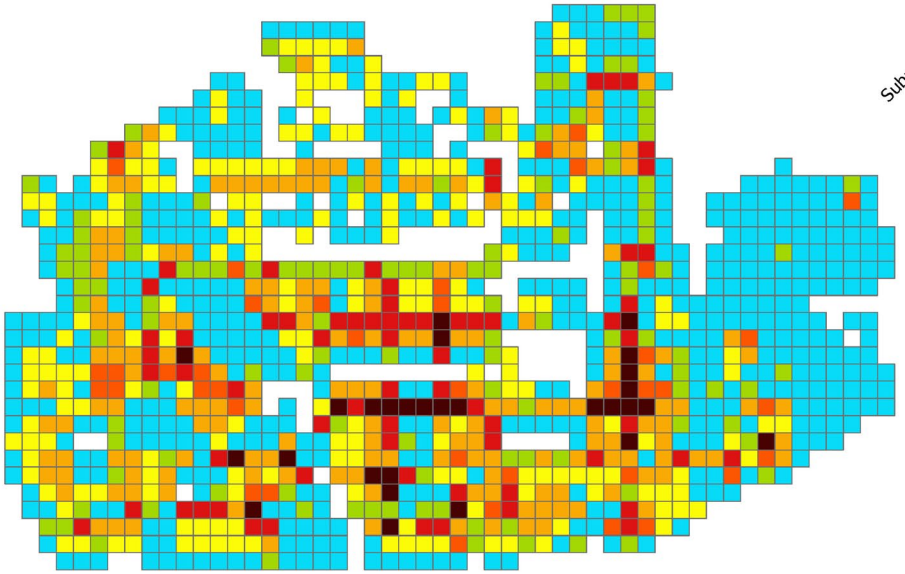
B. Various interventions in Songjiang new town for promoting higher degree of urbanity

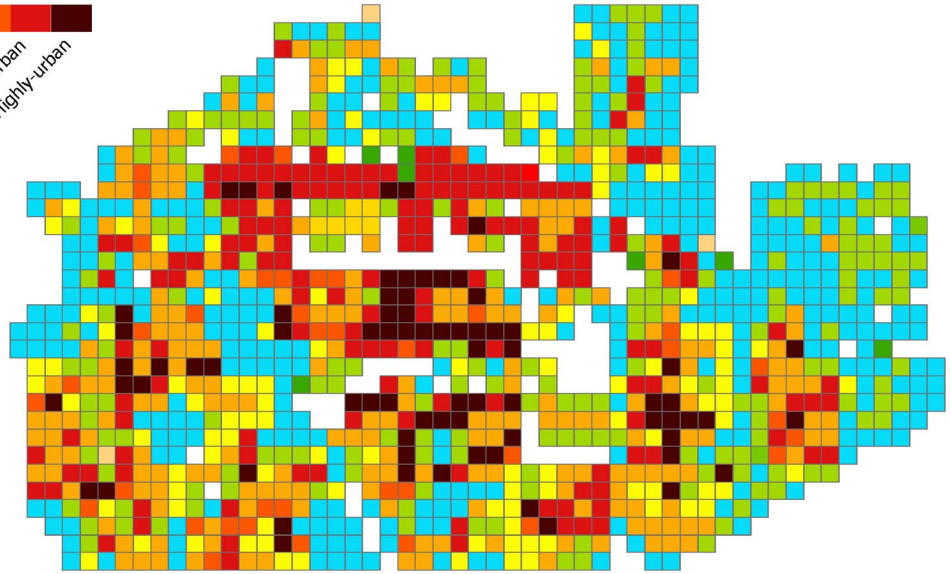




05.4 THE EXAMPLE OF SOLUTION EVALUATION

Judging the impacts of design interventions by illustrating a before-and-after situation



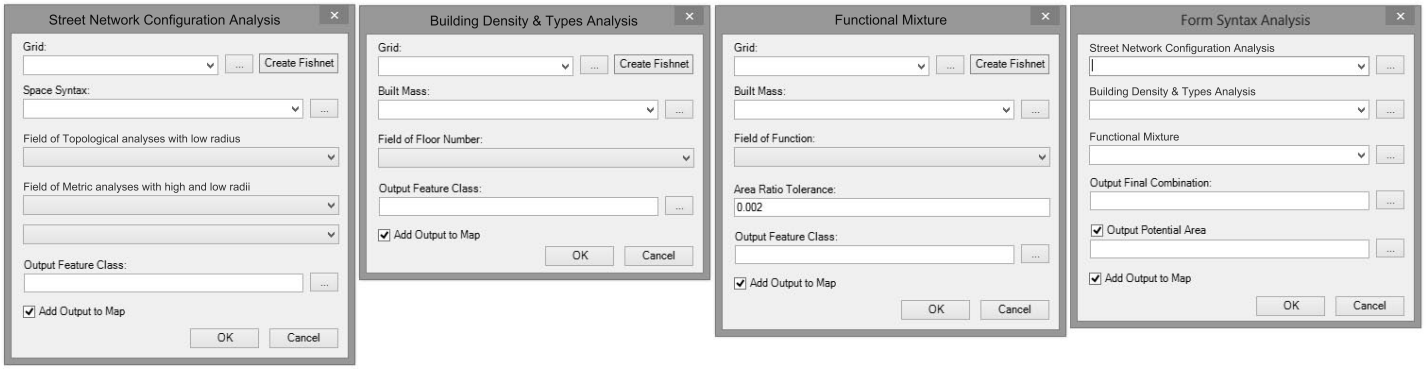


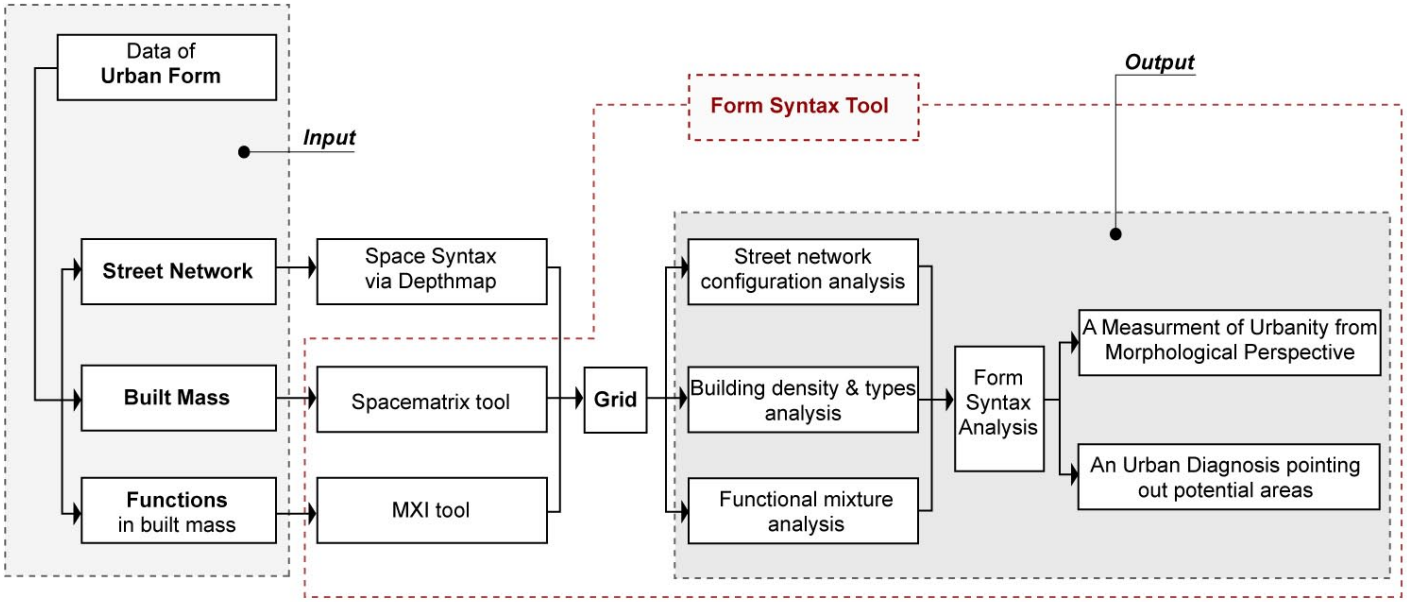
C. Analysis of Form Syntax in Songjiang new town before intervention

D. Analysis of Form Syntax in Songjiang new town after intervention

05.5 A GIS ADD-IN: FORM SYNTAX TOOL

The first three windows are used for street network configuration analysis, building density and types analysis, and functional mixture analysis. The last window can combine the results of three analyses for measuring urbanity and making urban diagnosis.





SECTION

06.

CONCLUSION

06.1 ADVANTAGES OF FORM SYNTAX

FORM SYNTAX APPLIES QUANTITATIVE GEO-TECHNIQUES FOLLOWING TRADITIONAL, INTUITIVE-BASED URBAN DESIGN PROCESSES:

It is easy to be understood by designers. Many phases of the urban design which traditionally inspired by intuition can now be assisted by a scientific-grounded method.

FORM SYNTAX'S DATA INPUT IS LIMITED AND OVERLAPS WITH CURRENT DESIGN ANALYSES.

Designers do not need to waste extra time for collecting data because the data required by Form Syntax is also used in other analyses.

FORM SYNTAX PROVIDES KNOWLEDGE ON URBAN MORPHOLOGY, WHICH IN TURN CAN ASSIST BETTER URBAN DESIGN:

Further research of internal spatial evolving “logic” of urban form, especially the interrelationship between the three essential properities, can help to produce better design.

06.2 SHORTCOMINGS & FUTURE DIRECTION

THE SHORTCOMING: FORM SYNTAX AS A GRID-BASED ANALYSIS MIGHT CAUSE DISTORTIONS IN DESCRIBING URBAN FORM WHICH IS ACTUALLY BASED ON BLOCKS AND PLOTS.

Form Syntax works well if appropriate grid size has been chosen

FUTURE DEVELOPMENT: FORM SYNTAX AS A GRID-BASED ANALYSIS CAN COMBINE OTHER SOCIO-ECONOMIC DATA

Thanks For Your Attention